1- Introduction

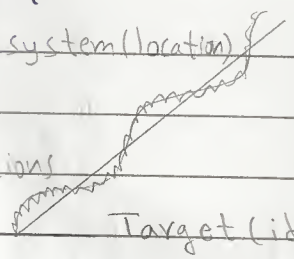
* - Hand tool → M/C is moved to w.p. to perform the function
  - M/C → W.P. is moved to M/C to perform the function

- Microscope is a m/c
- Micrometer is a hand tool

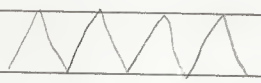
* Inclination, straightness & roughness:

- Inclination: due to wrong fixing of system (location)

- Out of straightness: due to deflections due to wrong or unsufficient fix of w.p. or any part of the system

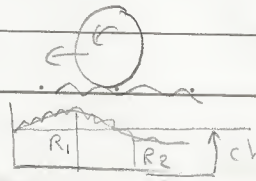


- Roughness: due to process conditions as speed, feed, etc.
- Roughness type needed depends on the needed application (Painting/lubrication/...)



High λ & Amp. Low λ & Amp.

- Roughness is separated from straightness during measuring
  Big anvil → out of straightness → large scale
  → low accuracy
  Small anvil → Roughness → small scale
  → High accuracy
- Small anvil + large scale → Breaking down
- 2 dimensions → Flatness instead of straightness
  Circular → Eccentricity is considered



Subject. 2 Date.

2- Thread measurements

* Main parameters in thread to be measured:

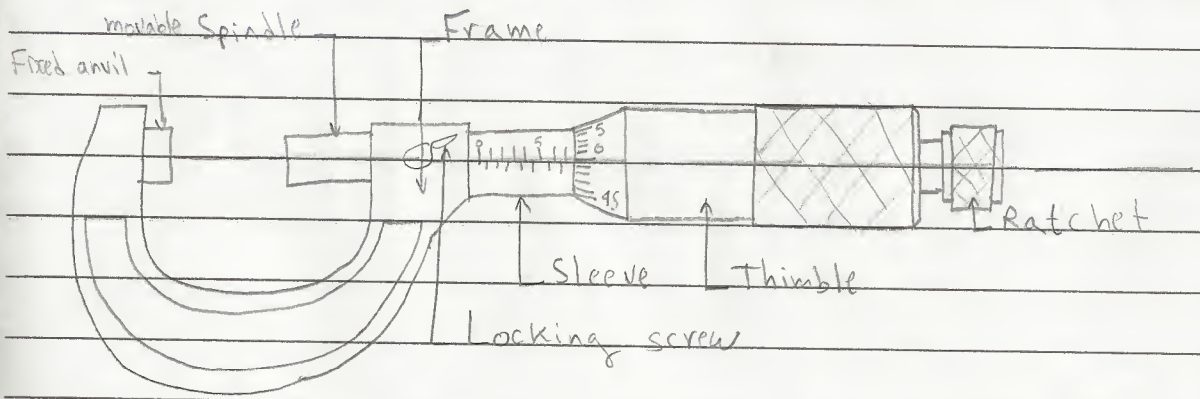
1- Outer diameter
2- Inner diameter
3- Effective diameter
4- Included angle
5- Flank angle
6- Pitch

* Used tools:

A- Hand tools:
1- Micrometer
2- Dial gauge

B- M/C tools:
1- Tool maker microscope
2- Projector
3- Abbe vertical metroscope
4- Abbe horizontal metroscope

A-1- Micrometer:

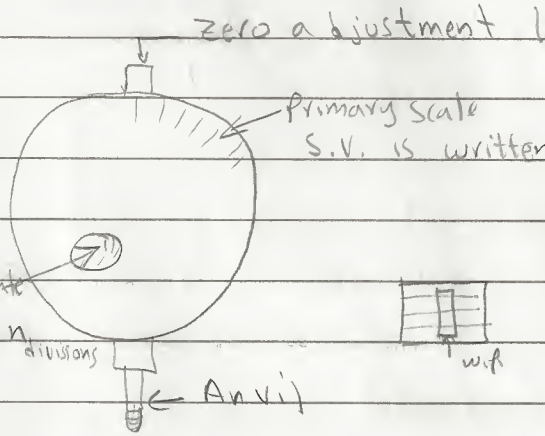


1- Hold the micrometer from frame
2- Define S.V. of micrometer

3- Close the micrometer to end or use block gauge to find zero error
4- Use ratchet at final closing
5- Consider the below scale
6- Reading = $N_1 \times S.V._{\text{main scale}} + N_2 \times S.V._{\text{thimble scale}}$ + zero error + Anvil length
7- Repeat reading
- Consider reversed scale reading as in internal micrometer

2- Dial indicator:

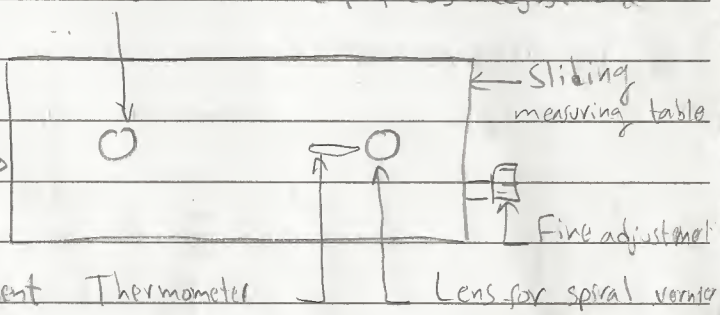
1- Use comparator
2- Take rough measure of w.p. (R)
3- Collect the reading (R) using block gauges (x)
4- Read the measurement of dial indicator (R_1) ⊥ scale
5- Read the measurement of w.p (R_2) ⇒ Max. reading

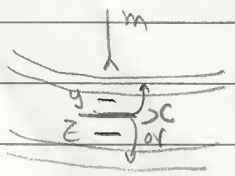


- $D_{w.p.} = x + R_2 - R_1$
- There are internal, external & depth dial gauges
  ↳ Anvils are considered

3- Abbe horizontal metroscope:

1- Adjust the w.p. under ocular head
2- Adjust the focus at ocular head
3- Move the table force/fine adjustment to one side of w.p and measure the spiral vernier
4- Repeat at other side





$y < z$ ⇒ $x + y + m$

Measure − $R_2 - R_1$

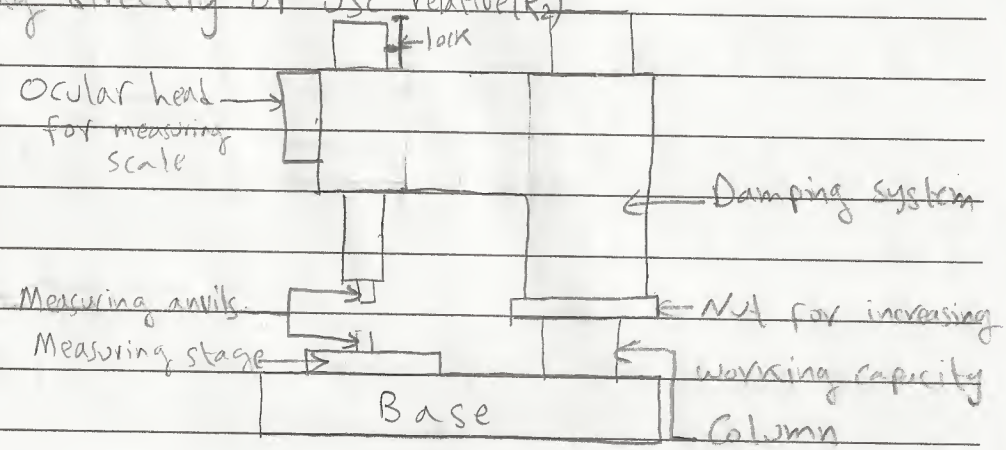
4- Abbe vertical metroscope:

1- Take intial reading including anvils zero error (R_1)

2- Take the reading directly or use relative(R_2)

3- $D = R_2 - R_1$

- Use lock to fix measurement



5- Microscope:

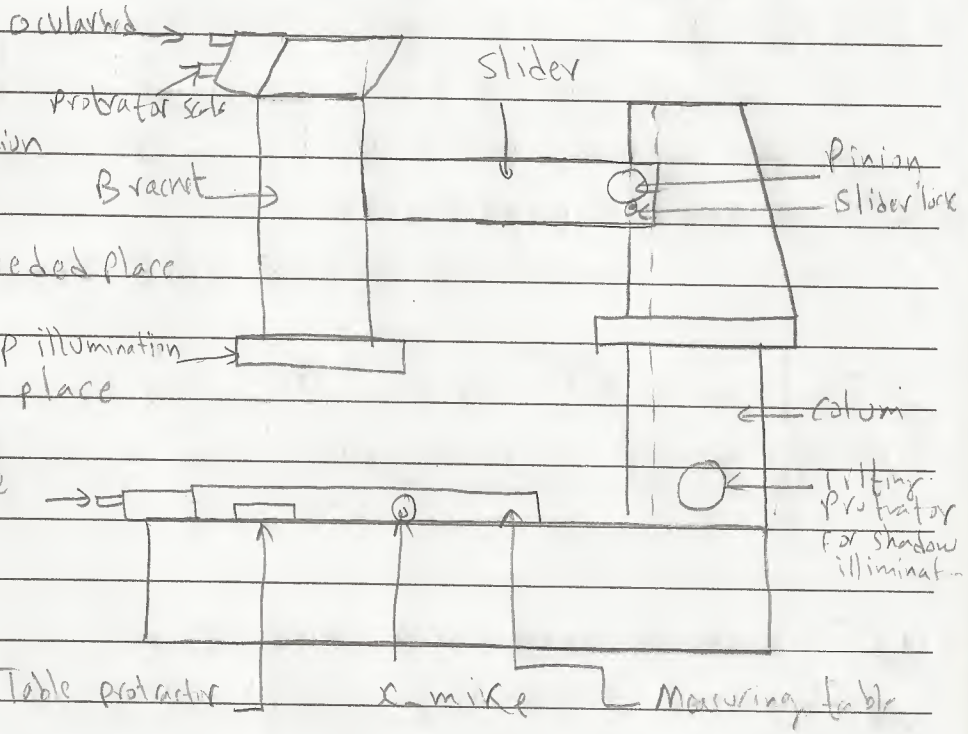
1- Adjust focus using pinion

2- set proctors to 0°

3- Move mike to needed place & take reading (R_1)

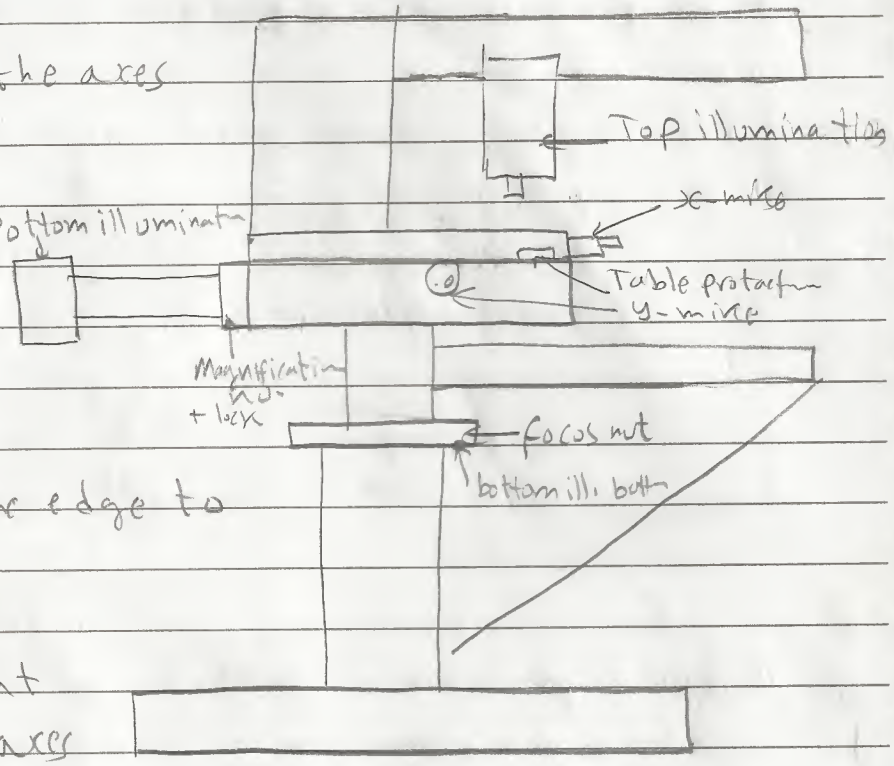
4- Take R_2 for end place

$D = R_2 - R_1$



6- Contour projector:

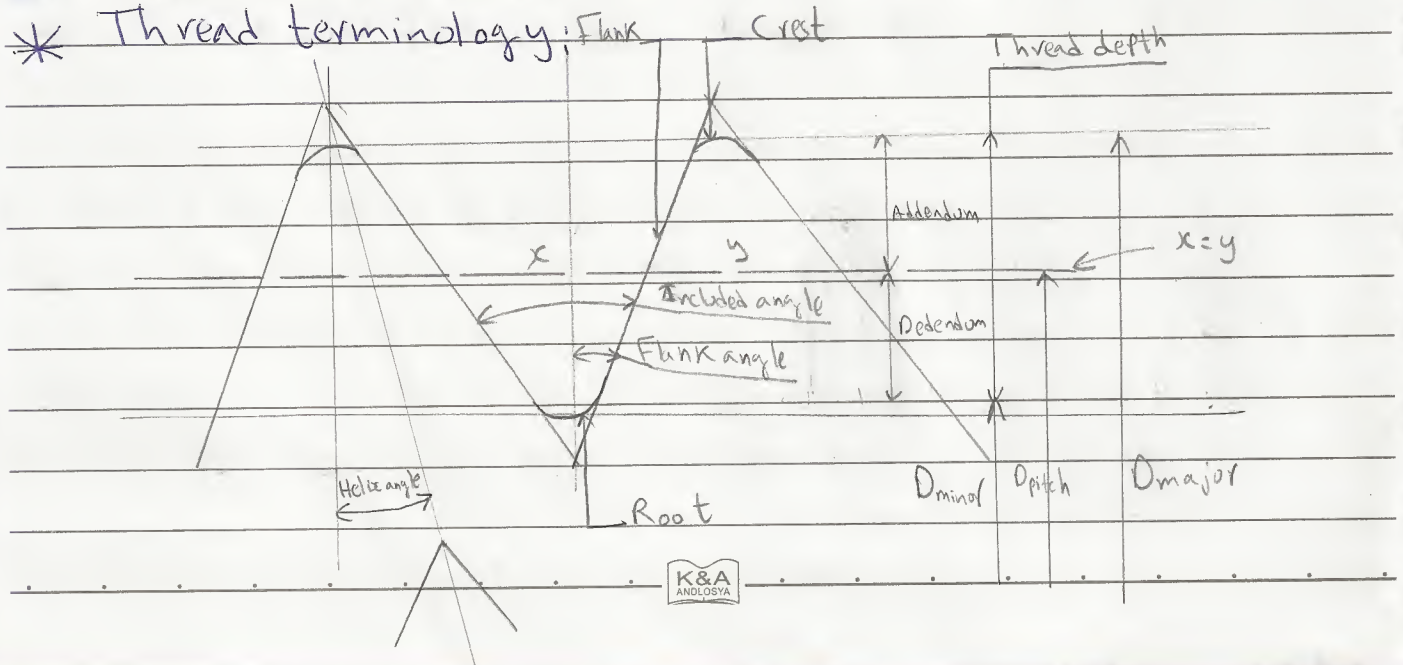
1- Use B.Gs to set the axes of table
2- Adjust the focus for best view
3- Put point at edge of B.G.
4- Move x-mike
5- Put point at same edge to get x-axis
6- Repeat for y-axis
7- Put w.p. in right position w.r.t. to axes using mikes of protractor
8- Measure dimensions by mike & protractor



- Radius  $\Rightarrow R = \frac{\text{Measured}}{\times}$
- Angles aren't magnified and measured by protactor & mikes

A- External thread measurements:

* Thread terminology:



1- Major diameter measurement:

A- Hand tools:

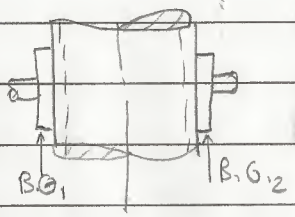
1- $R_1 = R_{BG_1} + R_{BG_2}$ + zero error

2- $R_2 = D_{major} + R_1$

3- $D_{major} = R_2 - R_1$

4- Repeat at different poistions

5- $D_{major} = \frac{\sum_1^n D_i}{n}$



B- Abbe vertical metroscope:

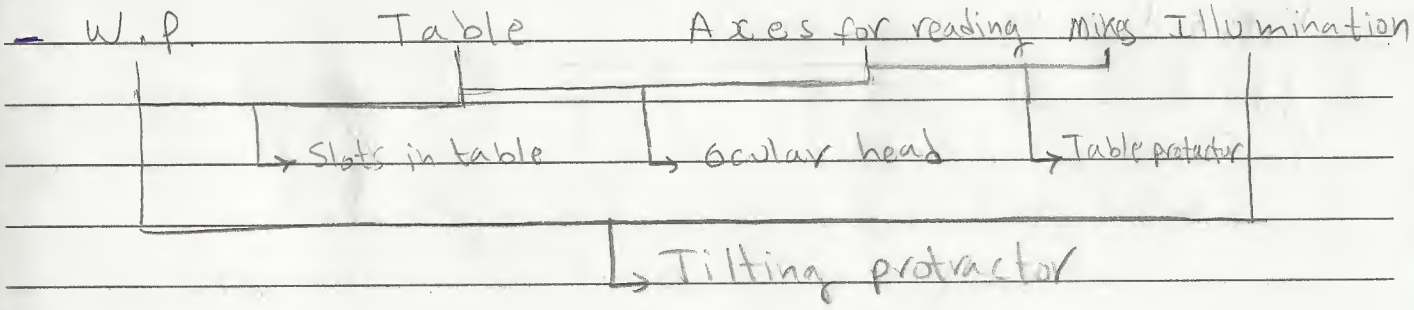
- As hand tools but - $R_1 = R_{BG_1} + R_{BG_2} + R_{anvils}$ + zero error
- Lock reading

C- Tool maker microscope: Top/bottom illumination

1- Adjust focus using pinon for fixed thread between 2 Centres

2- Readings of all protractors are zero

3- $D = R_2 - R_1$



D- Contour projector: Top/bottom illumination

1- Adjust focus using nut on B.G.

2- Draw axes

4- Adjust focus for w.p.

5- $D = R_2 - R_1$ at crests

- W.p. is moved by hand or using protactor to be with one axis (long way)

E- Abbe horizontal metroscope

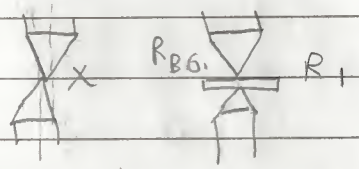
F- Dial gauge comparator

G- Cam shaft tester

2- Minor diameter measurement:

A- Hand tools:

- As major diameter measurement but anvils are different

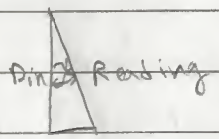


Misalignment

$$\text{Reading} = R_2 - R_1 + R_{B.G.}$$

$$D_{in.} = \text{Reading} \times \cos\psi$$

$$\tan\psi = \frac{\text{Lead}}{\pi D_{eff.}}$$



B- T. M. microscope:

- As major diameter measurement but tilting head occurs [$D_{eff.}$]

C- Contour projector:

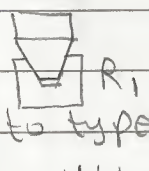
- As major diameter measurement but tilting W.P. occurs [$D_{eff.}$]

3- Pitch diameter measurement:

A- Hand tools:

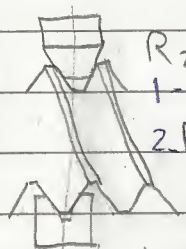
1- Thread micrometer:

- Anvils are selected according to type of thread & pitch



1M 1W ← 1 tooth/inch ⇒ $P = \frac{25.4}{1}$

P=1mm → 2M 2W



1- Select anvils

2. $D_{pitch} = R_2 - R_1$

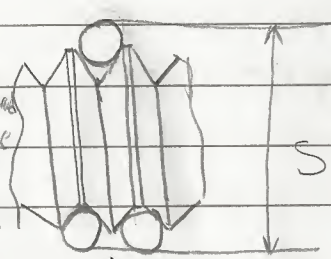
2- Three wire method

1- $d_{best} = \frac{P_{std}}{2} \sec\theta_{std}$ → larger ⇒ to be overthread

Using thread gauge → Flank angle

2- $S = D_e + d(1 + \text{cosec}\theta_{std}) - \frac{P_{std}}{2}\cot\theta_{std}$

$d = \frac{2d_{measured}}{2}$



2 for supporting

- $\theta = 30°, 27.5°$

B_ Abbe vertical metroscope;

_ As 3_wire method

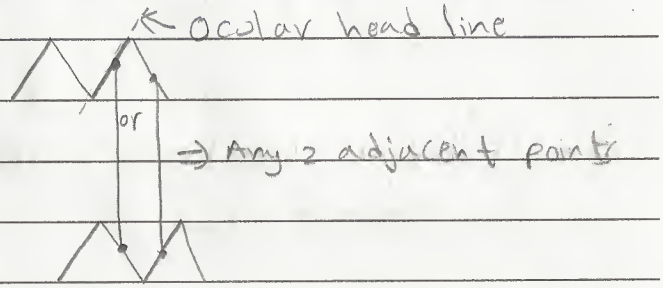
C_ T.M. microscope; Top illumination

1_ Using tilting protractor to eliminate shadow effect;

A_ Take intial tilting ψ_1

B_ Measure effective diameter De_1

$\psi_2 = \frac{1}{2}\tan^{-1}\frac{P_{std}}{\pi De} = 3.5^\circ$



C_ Tilt by ψ_2

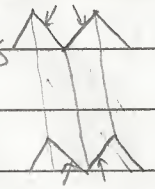
D_ Measure effective diameter De_2

E_ Repeat till $\psi_{n+1} - \psi_n \leq 0.5^\circ$ (S.V. tilting protractor)

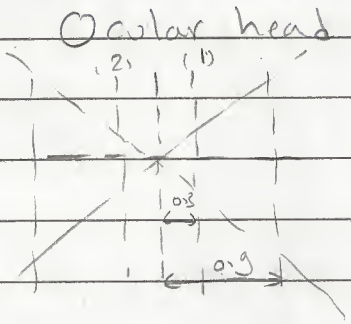
2_ Using knives to eliminate shadow effect;

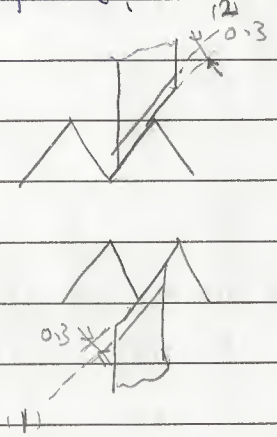
_ $\theta_{tilting} = 0^\circ$

_ 2 readings



Misalignment elimination





D_ Contour projector;

_ Use angle gauges under V blocks or 2 B.Gs and use bottom illumination

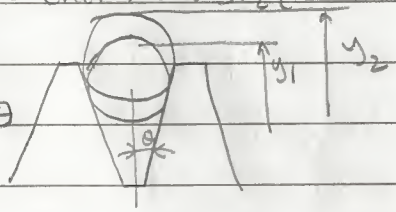
_ Shadow is present but considered as random error

4- Included angle measurement;

A- Hand tools;

- Use wires in Deff. and other more size

$$\sin\theta = \frac{dw_2 - dw_1}{(y_2 - dw_2) - (y_1 - dw_1)} \rightarrow \theta_{Incl.} = 2\theta$$



B- Abbe vertical metroscope;

- As hand tools

C- T.M. microscope;

- Using ocular head (S.V.↓) : Direct reading (2 up & 2 down)

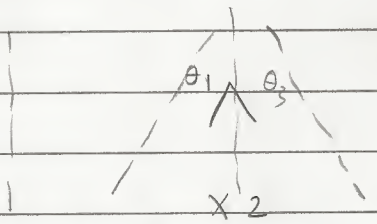
D- Projector;

- Using x & y mixes and table protactor considering (2 up & 2 down) centre of table
- Using direct measuring (X isn't considered)

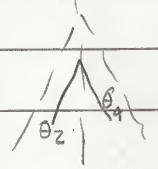
5- Flank angle measurement;

A- T.M. microscope;

- 4 reading up & 4 reading down
- Using knives



$$\theta_l = \frac{\theta_1 + \theta_2}{2}, \quad \theta_r = \frac{\theta_3 + \theta_4}{2}$$ for misalignment elimination



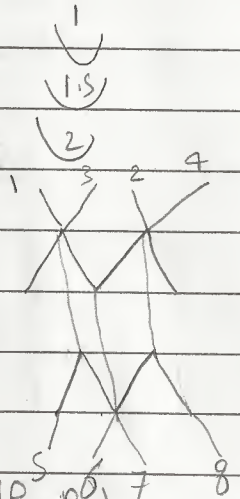
B- Contour projector;

- As T.M. microscope by 2 ways

6- Pitch measurement;

1- T.M. microscope;

A- Template for pitch



B- 8 readings

$$P = \frac{(R_4 - R_3) + (R_2 - R_1) + (R_6 - R_5) + (R_8 - R_7)}{4}$$

2- Contour projector;

- As T.M. microscope

3- Thread terminologies

* Types of threads according to form of surface: Peaks locus
1- Straight
2- Taper: Gas & liquid tubes
Self sealing & fast clamping
3- Horizontal: Spiral thread as in jaw chuck

* Types of threads according to form of profile: Shape of tooth
1- Triangular
2- Trapezoidal
3- Square
4- Round (in case of food cans)
5- Band S worm (Type of threads)

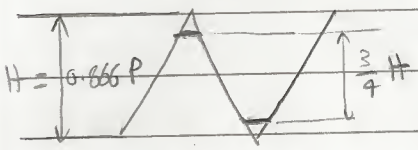
* According to no. of starts:
1- Single
2- Double Lead = iP
3- Multi ↳ no. of start

* According to sense of rotation:
1- Right hand (Right hand to close)
2- Left hand

* According to function:
1- Fastener
2- Power screw

* According to fineness:
1- Coarse pitch (High loads)
2- Fine pitch.

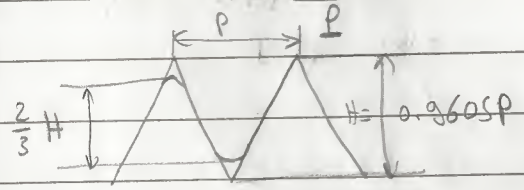
1- Metric thread
French std
$2\theta = 60°$
M ϕ x P
Nominal ϕ → Pitch size



$$0.866 = \frac{1}{2\tan 30°}$$

2- Whitworth thread
British std
$2\theta = 55°$
W ϕ x P
Nominal ϕ → No. of teeth/inch

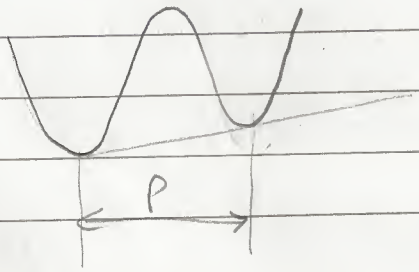
$$P = \frac{25.4}{P}$$



$$0.960S = \frac{h}{2\tan 27.5°}$$

3- Parallel pipe thread (G):
- As whitworth but round surface to prevent clearance

4- Taper pipe thread:



* Thread manufacturing:
1- Turning
2- Rolling (High tensile bolts)
3- Milling
4- Tapping
5- Casting

* Terminologies:

1- Screw thread: It is a continuous helical groove of specified cross-section produced on the external/internal surface

2- Crest: It is the top surface joining between 2 sides of thread

3- Root: It is the bottom of the groove between 2 flanks

4- Flank: It is the surface between crest & root

5- Lead: It is axial motion of nut on thread on rotating one rotation

6- Pitch: It is the distance measured parallel to axis of thread from point on thread to next corresponding point

7- Helix angle: It is the angle made by helix of thread at pitch line with axis

8- Flank angle: It is the angle between flank & normal to thread axis

9- Depth of thread: It is the distance between crest & root

10- Included angle: It is the angle between the flanks of thread measured in axial plane

* Errors in thread:

1- Major diameter error

2- Minor diameter error

3- Effective diameter error

4- Pitch error

5- Flank angle error

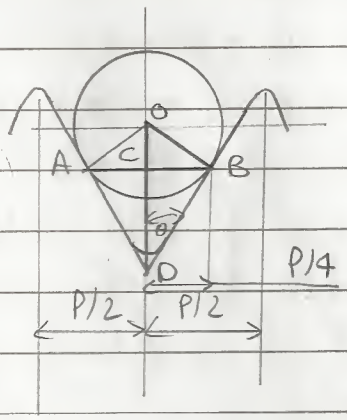
6- Included angle error

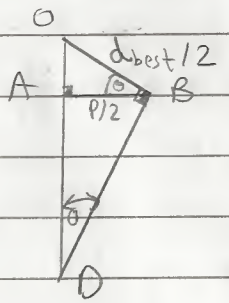
* Best wire diameter:

- Contact is at pitch line

$$\frac{d_{best}}{2} = \frac{P/2}{\cos\theta}$$

$$d_{best} = \frac{P}{2}\sec\theta$$



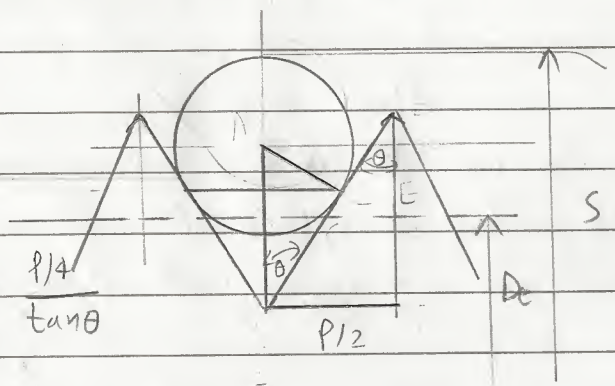


* Effective diameter calculations using wires method:

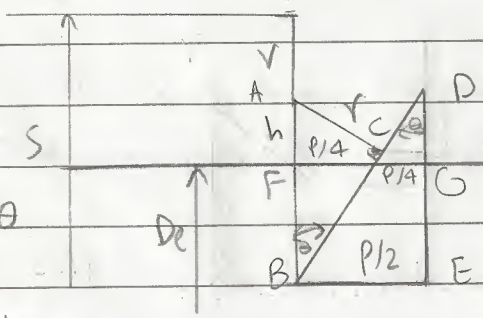
$$S = D_e + 2h + 2r$$

$$h = AB - BF = \frac{r}{\sin\theta} - BF$$

$$BF = GE = DE - DG = \frac{P/2}{\tan\theta} - \frac{P/4}{\tan\theta}$$



$$h = \frac{r}{\sin\theta} - \frac{P}{4\tan\theta}$$



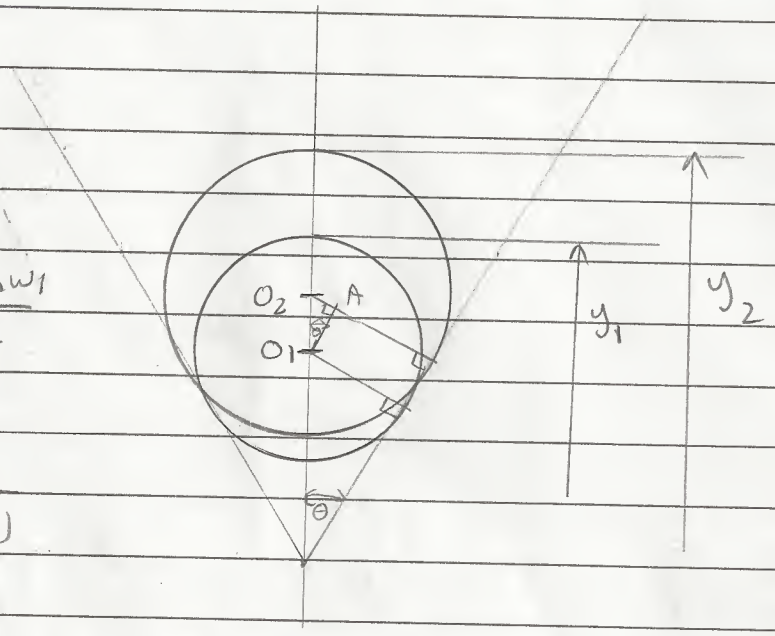
$$S = D_e + d + d\csc\theta - \frac{P}{2}\cot\theta$$

$$S = D_e + d(1 + \csc\theta) - \frac{P}{2}\cot\theta$$

$$D_e = S - d(1 + \csc\theta) + \frac{P}{2}\cot\theta$$

Subject. 151 Date.

* Included angle:



$$\sin\theta = \frac{O_2A}{O_1O_2}$$

$$O_2A = r_2 - r_1$$

$$O_1O_2 = \frac{y_2 - \delta w_2}{2} - \frac{y_1 - \delta w_1}{2}$$

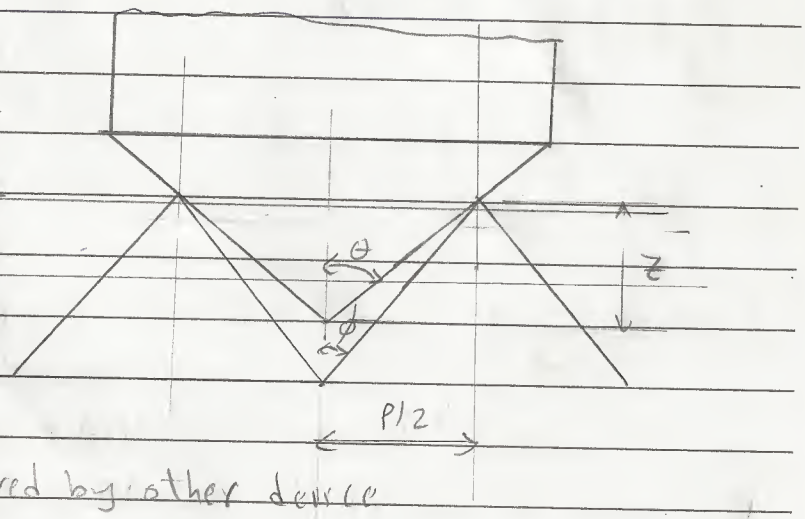
$$\sin\theta = \frac{d_2 - d_1}{(y_2 - \delta w_2) - (y_1 - \delta w_1)}$$

* Effect of included angle error on (D_e):

(θ) Half anvil angle

(δ) Half thread angle

(δ) Error in pitch diameter



$$\tan\theta = \frac{P/2}{z}, \quad \tan\phi = \frac{P/2}{z+\delta}$$

$$\delta = z + \delta - z = \frac{P}{2}(\cot\phi - \cot\theta)$$

Measured by other device

* Virtual effective diameter: It is the real effective diameter including flank & pitch errors (Wrong diameter) but for engagement

- Corrected D_e = D_e − Rake error + Compression error

Due to helix angle, it makes ↓ ↳ Due to human force

$$\text{Rake error} = \frac{\cos\theta\cot\theta}{2\pi 2} \times \frac{L^2}{d} \times A^2\left(1 + A\sin\theta + A^2\sin^2\theta\right), \quad A = \frac{d}{T+d}, \quad T = S - 2d$$

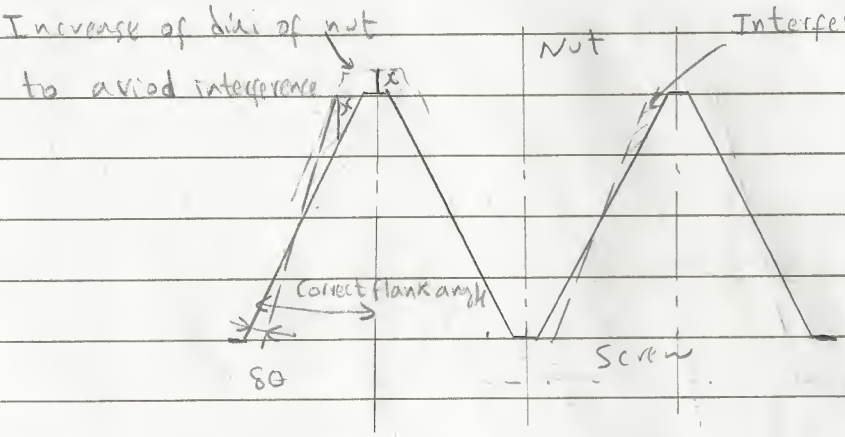
(θ) Half included angle (std), (L) Lead, (d) wire dia., (T) Distance under wires, (S) Measured dimension

$$\text{Compression error} = 0.001 \cdot \frac{F^{2/3}}{D_e^{1/3}}$$

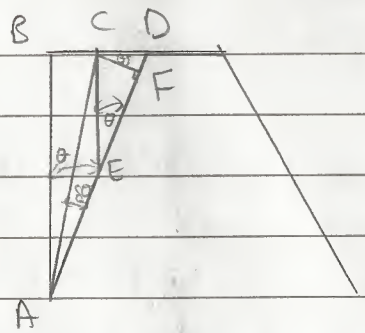
(F) Measuring force [N] ↳ from rake error

K&A ANDLOSYA

* Effect of flank angle error on (D_e):



$$\sin\delta\theta = \frac{FC}{AD}, \quad \sin\theta = \frac{FC}{CE}$$



For small ($\delta\theta$)

$\sin\delta\theta = \delta\theta$, $AC = AD$

$$\sin\delta\theta = \delta\theta = \frac{FC}{AC}$$

$$\sin\theta = \frac{FC}{CE} = \frac{AC\,\delta\theta}{CE}$$

$$\cos\theta = \frac{AB}{AD} = \frac{AB}{AC}$$

$$\cos\theta \times \sin\theta = \frac{AB}{CE}\delta\theta$$

, (AB = Half tooth depth)

$$AB = \frac{h}{2}$$

$$\cos\theta * \sin\theta = \frac{h}{2CE}\delta\theta$$

$$CE = \Delta D_e = \frac{h}{2\sin 2\theta}(\delta\theta_R + \delta\theta_L)$$

For metric thread

$$\Delta D_e = \frac{\frac{3}{4}\times 0.866P}{\sin 60^\circ}(\delta\theta_R + \delta\theta_L) \times \frac{\pi}{180} = 0.0131P(\delta\theta_R + \delta\theta_L)$$

For whitworth thread

$$\Delta D_e = 0.0160P(\delta\theta_R + \delta\theta$$

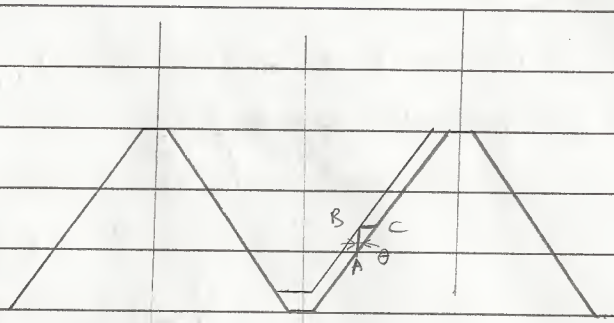
* Effect of pitch error on pitch diameter:

$$BC = \frac{\Delta P}{2}$$

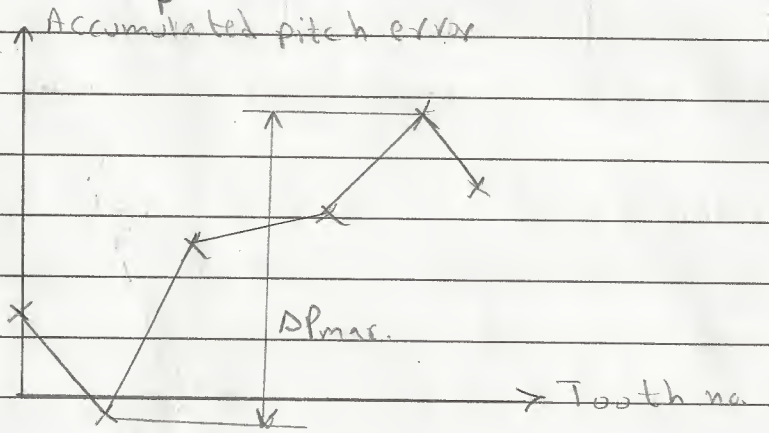
$$AB = \frac{\Delta D_e}{2} = \frac{BC}{\tan\theta}$$

$$\Delta D_e = \Delta P_{max} \cot\theta$$

Absolute



- No. of teeth $= \frac{H}{P} = \frac{0.7 D_o}{P}$

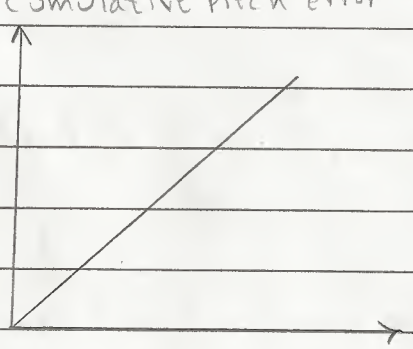


* Thread pitch errors:

1- Progressive error: The deviation (longer/shorter) of thread of pitch than nominal value due to:

A- Incorrect linear/angular velocity speed

B- Incorrect gear train or an app. gear train between w.p. & lead screw

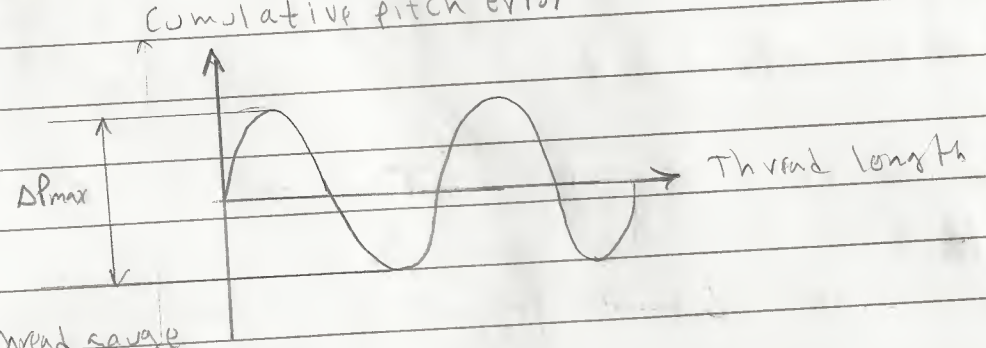


2- Periodic error: Repeated errors at regular intervals along the thread due to:

A- Non-uniform tool-work velocity ratio (variable)

B- Teeth error in gears

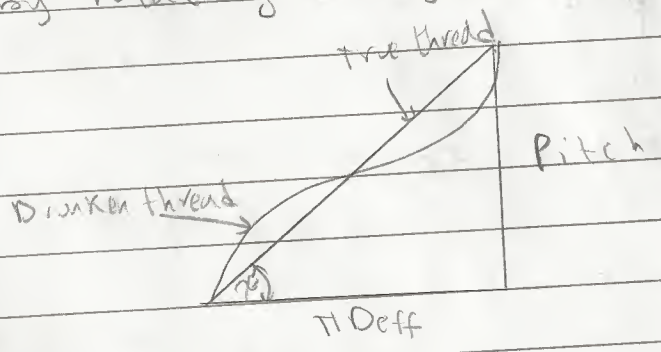
C- Lead screw error (axial movement)



ΔP = Pi - Pstd (by thread gauge)

3- Drunken error: Inside thread tooth in which helix is not true & drunken error is formed

- known by rotating nut by 90° ⇒ Lead ≠ Pitch



4- Irregular error: Pitch varies along the thread length in a regular manner due to:

A- Machine fault

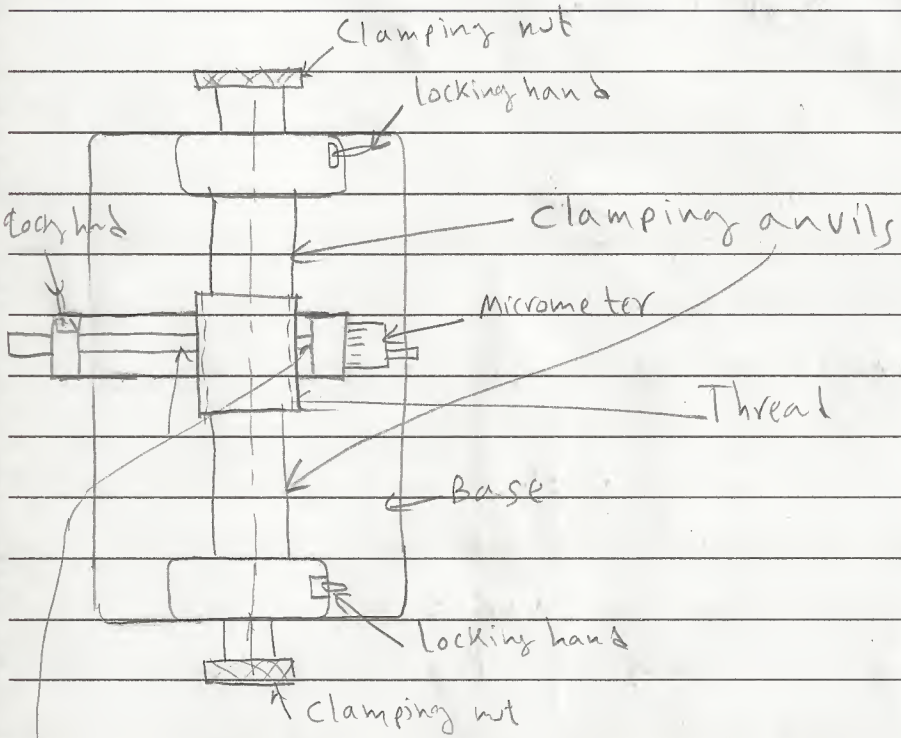
B- Non-uniformity in the material

C- Errors in cutting action

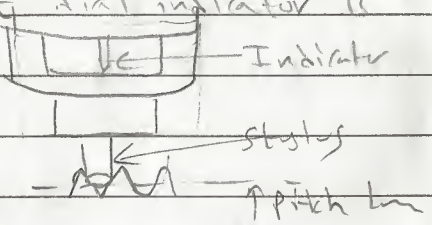
D- Mfg disturbance

* Virtual effective diameter: It is diameter of thread containing all errors

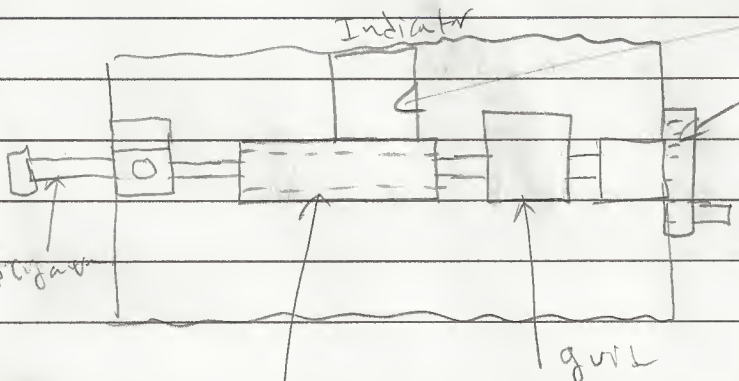
* Screw diameter measuring m/c:



* Floating carriage measuring m/c:
- As screw diameter measuring m/c but dial indicator is

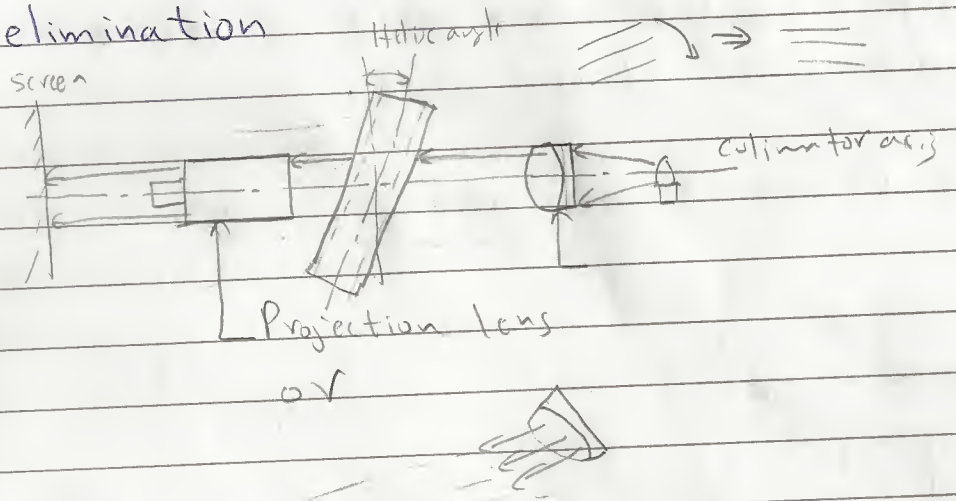


* Pitch measuring m/c:

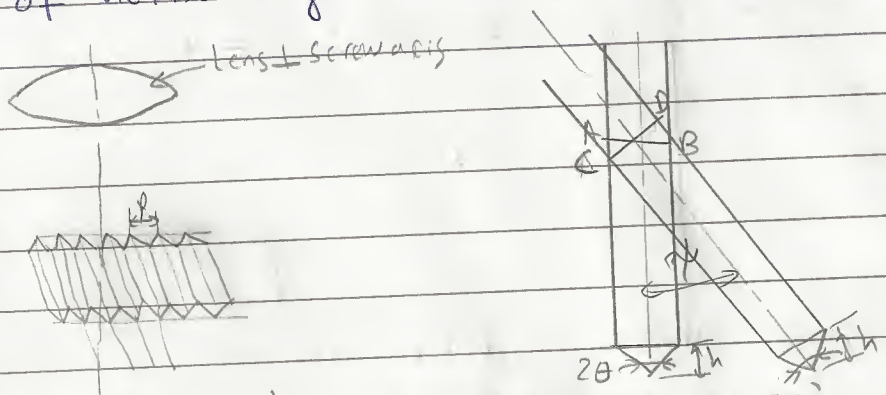


For same indicator readings Rmax is taken

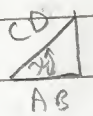
* Shadow elimination



* Effect of helix angle on measured thread angle;



(2θ) Thread angle in plane of screw axis
(2θ') Projected thread angle
(h) Tooth height
(P) Thread pitch
(ψ) Thread helix angle



$CD = AB \cos\psi = P\cos\psi$

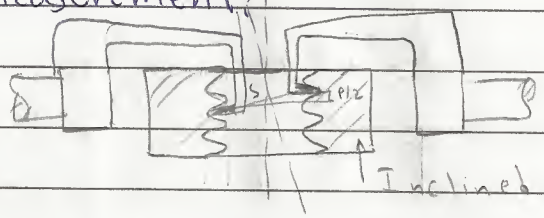
$\tan\theta = \frac{P/2}{h} \Rightarrow h = \frac{P}{2\tan\theta}$

$\tan\theta' = \frac{CD/2}{h} = \frac{P\cos\psi}{2\left(\frac{P}{2\tan\theta}\right)} = \cos\psi\tan\theta$

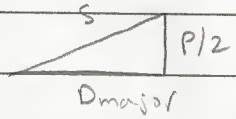
Subject. 21 Date.

B- Internal thread measurements: Bottom illumination is used

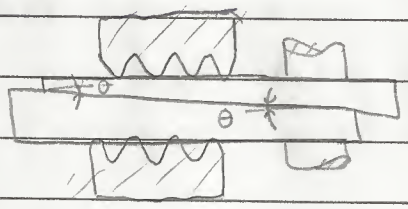
1- Major diameter measurement:

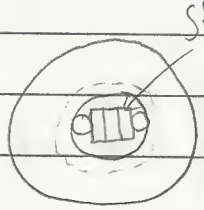


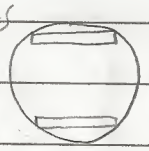
$$D_{major} = \sqrt{S^2 - \left(\frac{P}{2}\right)^2}$$



2- Minor diameter measurement:





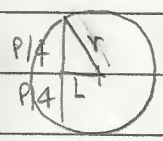


X ⇒ should be chamfered

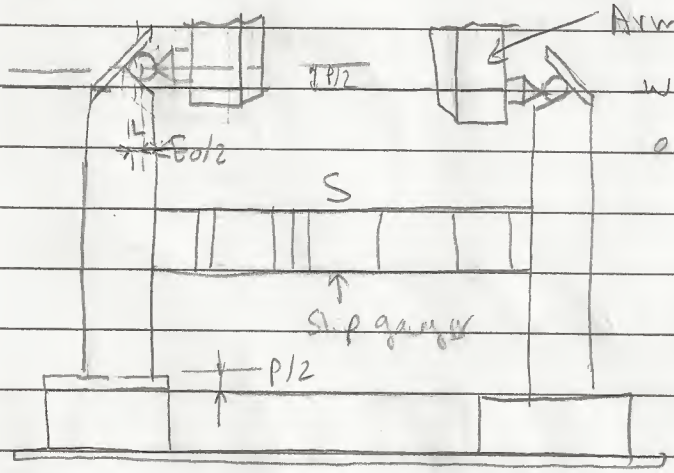
For D< 20mm For D>20mm (Long-time method → S.V.=0.001mm)

3- Pitch diameter measurement:

- Using internal horizontal comparator

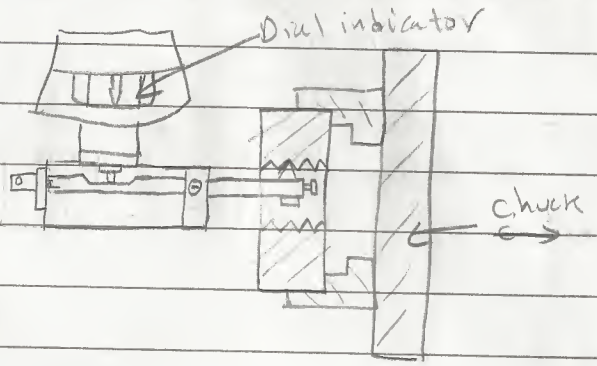


$$L = \sqrt{r^2 + \left(\frac{P}{4}\right)^2}$$



$$D_e = S + E_0 + 2L$$

4- Pitch measurement:

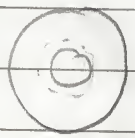


5- Flank angle measurement:

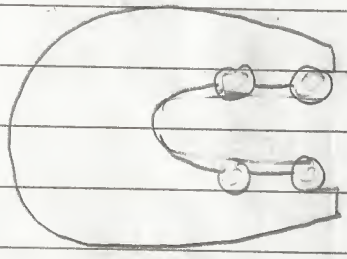
- Using plaster cast of the thread which is less than half the diameter of thread & lifted out ($\frac{1}{3}$)
- To avoid distortion, plaster cast shouldn't be screwed
- Using 3 balls.

* Checking screws: GO/NO GO [V.E.D.]

1- Thread ring gauge



2- Thread caliper gauge



3- Thread plug gauge